Oersted—the Discoverer of Electro-magnetism.[1]

On July 21, 1820, Hans Christian Oersted, of Copenhagen, announced his great discovery to the world in a circular letter in Latin, "Experimenta circa effectione conflictus electrici in acum magneticam." He describes in detail the apparatus he employed, emphasising the fact that "the galvanic circle must be complete, and not open, which last method was tried in vain some years ago by very celebrated philosophers," gives a list of distinguished men who had witnessed the new effect, and then writes:—

"Let the straight part of this wire"—*i.e.* the wire uniting the two poles of the battery—"be placed horizontally above the magnetic needle, properly suspended and parallel to it; if necessary the uniting wire is bent so as to assume a proper position for the experiment. Things being in this state, the needle will be moved, and the end of it next the negative side of the battery will go westward. If the distance of the uniting wire does not exceed three-quarters of an inch from the needle, the declination of the needle makes an angle of about 45°. If the distance is increased, the angle diminishes proportionally; the declination likewise varies with the power of the battery."[2]

A later communication[3] states that "he discovered by continual experiments during a few days the fundamental law of electro-magnetism, viz. that the magnetical effect of the electric current has a circular motion around it."

The Royal Danish Society of Sciences is celebrating the centenary of Oersted's discovery by the issue of a collected edition of his scientific papers, and the work before us is an essay by Mrs. Kirstine Meyer, forming the first volume of the collection.

H. C. Oersted was born at Rudkjobing in 1777. His father was an apothecary, and Hans Christian and his younger brother, A. C. Oersted, afterwards a distinguished jurist, received their early education from a German wigmaker and his wife, who taught them to read and speak German, but whose knowledge of arithmetic was limited to addition and subtraction; an older schoolfellow taught them multiplication; a friend of the family, division. From their eleventh and tenth years respectively they helped their father in his pharmacy. In 1794 they went to Copenhagen to finish their preparation for their first academic examination, which they passed with honours. As undergraduates they were admitted to Elers College, founded in 1691, which still provides free residence and a small scholarship for needy students. They went through the university course together with distinction, studying mathematics and chemistry, and being greatly interested in philosophy. Kant's teaching was then expounded in Copenhagen by Prof. Riisbrigh, and his lectures markedly influenced them. The lectures on astronomy and physics attracted H. C. Oersted to the study of science; his brother became distinguished for his philosophical writings; but throughout Hans Christian's life we can trace the effect of his early philosophical studies in his work. In 1798 he writes: "I promised you in our last conversation to give you an account in letters of the systematic part of chemistry. . . . I keep my promise with pleasure both for your sake and for that of science, which you know I find so much pleasure in communicating to others." The same year the brothers became members of the editorial staff of a short-lived journal, a philosophical repertorium, the chief object of which was to defend Kant's works.

As regards experimental work, the elder Oersted was limited mainly to the chemical training received in pharmacy where he was employed; the university had no physical equipment. He was helped, however, by Prof. Manthey, professor of chemistry, and owner of the Lion Pharmacy. Manthey was abroad during 1800 and 1801, and Oersted managed his pharmacy. Volta's discovery of the galvanic battery had just been published, and Oersted's earliest experiments were connected with the behaviour of various forms of cells and with the testing of a theory, advanced by Ritter, to account for the decomposition of water by a current: that water *plus* negative electricity produced hydrogen, while water *plus* positive electricity produced oxygen. He measured his currents for these experiments by the aid of a voltameter arranged to collect in a graduated tube the products of the decomposition.

In 1801 Oersted had hopes of a professorship or readership in the university, but he was then looking forward to the prospect of a journey abroad, rendered possible by a grant from "Cappel's Travelling Legacy"; and in a letter to Manthey he says that he would rather resign any post than give up the prospect of the journey. He started in the summer of 1801, and was away until the end of 1803. For a time the world was at peace. Napoleon was First Consul; the war between France and Austria was stayed temporarily by the Peace of Lunéville (February, 1801). The victory of the Nile, 1798, and of Aboukir Bay, 1801, ruined the French plans for an attack on India through Egypt, while access to the Baltic and the defeat of a combination of the Northern Powers against England were secured by Nelson's victory at Copenhagen in April, 1801. The Peace of Amiens followed in March, 1802, and intercourse between men of science of all nations was at once renewed. To us, in 1921, the rapidity with which this took place is somewhat surprising.

Oersted went first to Weimar. At Göttingen he was introduced to Ritter, whose electrical researches impressed him greatly. From Weimar he went to Berlin, where he heard Fichte and Schlegel lecture. At Weimar he had become acquainted with a work by Winterl, "Prolusiones ad Chemiam Decimi Noni," and set himself to make this more widely known, publishing in 1802 a book, "Materialen zu einer Chemie des neunzehnten Jahrhunderts," the object of which was to show the common origin of physical and chemical forces. The book was severely criticised everywhere, and Winterl's chemistry, founded on two mysterious substances, Andronia and Thelycke, has long since been consigned to the oblivion it deserved; but the root-idea, the common origin of most natural forces, lay at the basis of much of Oersted's future work.

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[1] "Scientific Life and Works of H. C. Oersted." By Kirstine Meyer. (From H. C. Oersted: "Scientific Papers," vol. i.) Edited by the Royal Danish Society of Sciences. Pp. clxvi. (Copenhagen: Andr. Fred. Høst and Son, 1920.)

[2] Thomson's "Annals of Philosophy," vol. xvi. (1820), translated from a Latin account sent by the author.

[3] "Edinburgh Encyclopædia," vol. xviii. (1830).

From Berlin Oersted went to Paris, visiting Ritter at Weimar on the way, and taking part in some of his experiments. On describing these in Paris, especially the invention of what was probably the first storage battery—a storage column, Ritter called it: a pile of copper plates separated by discs of moist cardboard, which retained a charge for some time after it had been connected to a battery, and was capable itself of giving out a current when its extremities were connected by a wire—Biot asked him to write and advise Ritter to compete for a prize of 3000 livres offered by the First Consul for the most important electrical or galvanic experiment which might compare with the invention of the voltaic pile.

Oersted re-wrote in French the essay Ritter sent in, but the author had stated that his storage column, when placed in a vertical position, became charged through the electrical influence of the earth. Experiments at Paris failed to verify this, and the prize went elsewhere.

Oersted returned to Copenhagen in January, 1804, and was disappointed at not receiving the professorship of physics, which had been vacant for some time. The warden of the university considered him a philosopher rather than a physicist, and it was not until 1806 that he became professor extraordinarius. In 1807 he repeated and extended Chladni's work on vibrating plates, using Lycopodium in place of sand. He noted, but could not explain, the action of the Lycopodium in collecting in the places of maximum vibration; that was left for Faraday.

In 1812 and 1813—the years of Moscow and Leipzig—Oersted again visited Berlin and Paris, and, encouraged by the reception he met with, published his "View of the Chemical Forces of Nature," in which, while expressing his indebtedness to Ritter and Winterl, he dissociates himself in many respects from their theories. He avows his continued belief in the essential unity of natural forces, and, while his views are often vague and unsatisfactory, he proposes that "the experiment should be made whether electricity in one of its most latent forms could act on the magnetic bodies as such." The answer came in 1820. The book was well received everywhere. Thomson writes in the "Annals of Philosophy, 1819," dealing with a later French edition: "The book is highly worthy the perusal of all those British chemists who aim at the improvement and perfection of their science. It is rather surprising that a work of such originality and value should have remained for these four years quite unknown in this country."

In the years which followed, Oersted was busily occupied with routine work. In 1815 he became secretary of the Society of Sciences, and in 1817 professor ordinarius. In this capacity he delivered a series of monthly lectures to advanced students on the progress of science, and it was at one of these in the spring of 1820 that his great discovery was made. His own description of this will be found in the article in the "Edinburgh Encyclopædia" already referred to. After stating that the luminous and heating effect of the electrical current goes out in all directions, "so he thought it possible that the magnetical effect could likewise eradiate"; and after referring to magnetic effects produced by lightning, he continues: "The plan of the first experiment was to make the current of a little galvanic trough apparatus commonly used in his lectures pass through a very thin platina wire which was placed over a compass covered with glass. The preparations for the experiment were made, but, some accident having hindered him from trying it before the lecture, he intended to defer it to another opportunity; yet during the lecture the probability of its success appeared stronger, so that he made the first experiment in the presence of his audience. The magnetical needle, though included in a box, was disturbed; and as the effect was very feeble, and must, before its law was discovered, seem very irregular, the experiment made no strong impression on his audience." Nothing further happened for three months; he delayed his researches until a more convenient time, when a large battery, constructed by his friend Esmark and himself, was available, and then, during a few days in 1820—July 15–20—he made the series of experiments which was announced in the Latin circular letter of July 21 already quoted.

A letter from his pupil Hansteen to Faraday, printed in Bence Jones's "Life of Faraday," gives a fuller account of the original discovery: "At first he had placed the wire at right angles to the direction of the magnet, and found no effect. After the end of the lecture he said: 'Let us now once, as the battery is in activity, try to place the wire parallel to the needle'; as this was made, he was quite struck with perplexity by seeing the needle make a great oscillation almost at right angles with the magnetic meridian. Then he said: 'Let us now invert the direction of the current,' and the needle deviated in the contrary direction. Thus his great detection was made, and it has been said, not without reason, that he tumbled over it by accident. He had not before any more idea than any person that the force should be transversal. But, as Lagrange has said of Newton on a similar occasion: 'Such accidents only meet persons who deserve them.'" Hansteen's remark would appear to do less than justice to his master, and has proved rather unfortunate, lending colour to the impression that the whole discovery was due to chance. This was far from being the case. Oersted had for years been seeking a connection between electricity and magnetism, and the discovery was the result of his search.

Not the least instructive part of Mrs. Meyer's very interesting book is a series of sheets reproduced in facsimile from notes, mostly in his own handwriting, found among Oersted's papers, which give in detail the experiments with the large battery during July, 1820. Not only did he experiment with a straight wire, but also with one bent into a loop so as to form one complete turn of a circuit, which thus had its north and south face. Oersted saw that such a circuit acted like a magnet. The effect of replacing the magnet by needles made of non-magnetic material was tried, and it was found that they were not disturbed by the current.

The results, announced to all centres of scientific activity, at once produced a great sensation. The paper was published in various journals, and among others in Schweigger's *Journal* for July, 1820, and the same number contains an account of further experiments of importance. Oersted showed in this second communication that the effects "do not seem to depend upon the intensity of the electricity, but solely on its quantity"—in modern words, on the current, and not on the e.m.f. of the supply. Further, he showed, by suspending by a fine torsion wire a small battery and the circuit through which the current passed, that the effect is reciprocal: on bringing a magnet pole up to one face, the circuit is repelled; on bringing the same pole up to the other face, it is attracted.

But while Oersted's experimental work is admirable and his demonstration complete, it is not easy to follow his theoretical ideas. He speaks continually of the "conflict of the electricities" which constitutes a current. The positive and negative electricities flowing in opposite ways round the circuit come into conflict, and it is through their struggle that the various effects are produced. It would almost appear as though he thought that the heat and light radiated from a glowing conductor needed some violence for their origin—violence provided by the struggle between the positive and negative electricities. "He did not consider," he writes himself, "the transmission of electricity through a conductor as a uniform stream, but as a succession of interruptions and re-establishments of equilibrium in such a manner that the electrical powers in the current were not in equilibrium, but in a state of continual conflict." To this conflict he attributes also the magnetic action which originally he anticipated would be radiated outwards from the wire, like heat and light. Experiment proved otherwise; the magnetic action showed itself effective in directions at right angles to the wire, but he did not grasp the idea of a current of electricity flowing in the wire accompanied by a field of magnetic force arranged in circles round the path of the current. In his view, the electricity acted directly on the poles of his magnet, and as the force was due to the electric conflict, this conflict took place, not only in the wire, but also throughout the surrounding space through which the electricity flowed in a series of flat spirals encircling the wire itself. There was a transference of electricity in the direction of the wire; the path, therefore, of the current could not be a circle in a plane normal to the wire, but a spiral giving rise to a component of the motion parallel to the wire. According to his first ideas, though he modified these later, "negative electricity repels the north pole, but does not act on the south pole," while positive electricity acts on the south pole, but not on the north.

In 1828 Oersted writes thus, possibly after he had become aware of Faraday's work: "The electrical stream has a magnetic circulation about its axis. Every act of decomposition due to an electrical current in a given direction is accompanied by a circulation. Through this electrical stream, which, as I have shown elsewhere, is propagated by alternations of positive and negative electricity, there is brought about a series of charges and discharges of particles in the direction of the stream, and a circulation in planes at right angles to it."

The importance of this discovery was recognised everywhere. In Germany, at a somewhat later date, an attempt was made by Gilbert and others to lay stress on its accidental nature. "Was alles Forschen und Bemühen nicht hatte geben wollen das brachte ein Zufall Herrn Professor Orsted in Kopenhagen," he wrote in his *Annalen* in October, 1920, and this view was accepted by many of his contemporaries; but elsewhere Oersted received full and generous credit. The French physicists, led by Arago and Ampère, took up eagerly the investigation of the new phenomena, and in a few months Ampère established the laws of the mechanical action between electric currents. "The whole theory and experiment," writes Maxwell, "seems as if it had leaped full grown and full armed from the brain of the 'Newton of Electricity.' It is perfect in form and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electro-dynamics." Ampère's brilliant work somewhat overshadowed Oersted's merit, which, however, the French investigators fully recognised.

In England Sir Humphry Davy was the first to repeat the experiments, using for the work "the great battery of the London Institution, consisting of 2000 plates of zinc and copper"; he showed at an early date that the arc between two charcoal electrodes was altered in shape when a magnet was brought near. In April, 1821, Faraday wrote an historical survey of the growth of the subject up to date, stating that Oersted's results "comprise a very large part of the facts that are yet known relating to the subject," and pointing out that his constancy in the pursuit of his inquiries respecting the identity of chemical, electrical, and magnetic forces "was well rewarded in the winter of 1819 by the discovery of a fact of which not a single person besides himself had the slightest suspicion, but which when once known instantly drew the attention of all those who were at all able to appreciate its importance and value."

From the autumn of 1822 to the summer of 1823 Oersted was in Germany, France, and England. He is less enthusiastic than in the past about the German men of science whom he met. "Schweigger at Halle has brains, but is a reed shaken with the wind. His experiments are not of much importance. Kastner at Erlangen writes thick volumes compiled with much toil but without all judgment. Yelin at Munich makes indifferent experiments and lies much. But I have found much that was instructive with Fraunhofer at Munich, so that I have been able to occupy myself with benefit there for about a fortnight."

To the Frenchmen he is more kindly. "My stay here grows more and more interesting to me every day. The acquaintances I have made grow every day more cordial and intimate," he writes to his wife from Paris in February, 1823. He saw Biot, Fresnel, Pouillet, Ampère, Arago, Fourier, Dulong, and many others: such was the brilliant list of physicists then at work in Paris. With Ampère he had many discussions as to their rival theories; at one time he thought he had disproved the existence of the molecular currents which in Ampère's view constitute a magnet. Mrs. Meyer quotes from another letter an amusing account of a three hours' discussion which took place after a dinner given by Ampère. Among the guests were two of the host's pupils, and of them Oersted writes: "Even Ampère's two disciples declared that my theory was able to explain all his phenomena. They declare that so will Ampère's, and as his theory is nothing but the reverse of mine, he having removed the circuits of forces discovered by me from the conductor to the magnet, it will no doubt be difficult to find an entirely decisive objection to his theory."

The experiments which Ampère arranged for his benefit were not successful. "On the 10th I was at Ampère's by appointment to see his experiments. He had invited not a few. . . . He had three considerable galvanic apparatus ready; his instruments for showing his experiments are very complex; but what happened? Hardly any of his experiments succeeded. He is dreadfully confused, and is equally unskilful as an experimenter and as a debater." Somehow this is hard to believe; some at least of the confusion existed, we may suspect, in the mind of the narrator. Ampère's own descriptions of his work are models of clearness; his formula remains, as has been said above, "the cardinal formula of electrodynamics."

Oersted lived for some thirty years after the discovery of 1820, engaged almost to the last in physical work. During part of the time he was greatly interested in measurements of the compressibility of liquids. Details of some of these are given in a letter to Brewster dated December 30, 1826. He was one of the first to realise the necessity of allowing for the expansion of the vessel containing the liquid, and a piezometer which he described in the Proceedings of the Danish Society of Sciences for 1821 has been frequently employed for measurements of the kind, though Oersted was mistaken in thinking that it avoided all the difficulties arising from the expansion of the containing vessel.

Under date 1845 we have the following suggestion for a moving coil galvanometer: "A metal wire bent as a multiplier and able to revolve easily round two points is placed opposite the poles of a strong magnet in such a way that it will be deflected as soon as it is traversed by electricity."

In 1848 Denmark was at war, and in a letter of that date Oersted alludes to the fact that thirty years earlier he had experimented on the use of electricity for firing mines, and makes the suggestion of "burying in a road to be taken by an attacking enemy, under a comparatively thin layer of earth, small reservoirs filled with gunpowder and earth or small fragments of stones which could be fired by a communicating wire on a given signal and that in a shorter time than one second after the signal."

More will be found in Mrs. Meyer's excellent volume about the activities of a remarkable man; she has done her work admirably, and we are indebted to her for her labours in producing this most interesting work. The book, which is printed in English, has been published in Copenhagen under the editorship of the Royal Danish Society of Sciences, and is in every way a worthy memorial of perhaps the most distinguished member of that society.

R. T. G.

Native Life in the Loyalty Islands and Southern Nigeria.[1]

By HENRY BALFOUR.

(1) MRS. HADFIELD'S book on the Loyalty Islands is the outcome of a long residence in this group, in connection with the work of the London Missionary Society. The greater part of the time was spent on Lifu Island, but eight years were spent on the smaller island of Uvea. The account which she gives of the natives is unpretentious and straightforward, written in an easy and attractive style and with a vein of humour. She reveals her sympathy with the natives, with whom she became on excellent terms, and much

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[1] (1) "Among the Natives of the Loyalty Group." By E. Hadfield. Pp. xix+316 (London: Macmillan and Co., Ltd., 1920.) 12s. 6d. net.

(2) "Among the Ibos of Nigeria: An Account of the Curious and Interesting Habits, Customs, and Beliefs of a Little Known African People by One who has for Many Years Lived amongst Them on Close and Intimate Terms." By G. T. Basden. Pp. 315. (London: Seeley, Service, and Co., Ltd., 1921.) 25s. net.